AMENDMENT TO THE CLAIMS

1. (Currently Amended) A method for reducing emissions of common rail fuel system compression ignition engine without substantial reduction in acceleration, the method comprising running said engine on a fuel comprising a diesel fuel characterized by having a density of about ~~0.83~~ <u>0.825</u> g/cc or less, a viscosity of about ~~3~~ <u>2.6</u> cSt or less at 40°C, and a sulfur content of about 0.05 wt% or less.

2. (Cancelled)

3. (Previously Amended) The method of claim 1 wherein said density is about 0.820 g/cc or less.

4. (Cancelled)

5. (Cancelled)

6. (Cancelled)

7. (Previously Amended) The method of claim 1 wherein said viscosity is about 2.1 cSt or less at 40°C.

8. (Cancelled)

9. (Previously Amended) The method of claim 3 wherein said viscosity is about 2.1 cSt or less at 40°C.

10. (Previously Cancelled)

11. (Currently Amended) The method of claim 1, ~~2,~~ 3, 4~~, 5, 6,~~ 7~~, 8~~ or 9 wherein said sulfur content is about 0.04 wt% or less.

12. (Previously Amended) The method of claim 11 wherein said sulfur content is about 0.03 wt% or less.

REMARKS

The present invention is directed to the discovery that high pressure common rail fuel injected diesel engines can be run at a reduced emission output level using lower density fuels with a smaller loss in power than one would usually expect from the use of such lower density fuels in diesel engines based on the teachings in the literature. Such avoidance of significant power loss is achieved using the lower density fuel at the same fuel flow rate in the engine as is used for the more usual higher density fuels.

It is not surprising that low density fuels are environmentally preferred from an emissions stand point. This is already taught in the literature and is acknowledged in the present specification.

What is surprising is that such lower density diesel fuel can be used in high pressure common rail fuel injected diesel engines with a smaller loss in power than one has come to expect in regard to the use of such fuels in other types of diesel engines based on the teachings of the literature. See: Automotive Fuels Handbook, published by the Society of Automotive Engineers, Inc., 1990 by Owen and Coley, pages 340-344.

That article shows that fuel density is an important fuel characteristic with respect to fuel injection equipped diesel engines, that power goes down as fuel density decreases. The article suggests that a way to compensate for this power loss is to adjust the injection pump delivery for equal power to eliminate the density effect.

The Examiner rejects claims 1-9, 11 and 12 under 35 U.S.C. §103(a) as unpatentable over Barry, et al. (USP 5,976,201).

The Examiner argues that the Barry reference discloses a diesel fuel having a specific gravity typically in the range of 0.82 to 0.83 g/cc, a viscosity typically in the range of from 1.7 to 1.9 cSt at 40°C and a sulfur content of no greater than 0.1 wt%, with a specific example of a fuel with a sulfur content of 0.01 wt%.

The Examiner acknowledges that the reference does not disclose the use of the fuel in a common rail fuel system compression ignition engine.

Despite the acknowledged deficiency, the Examiner argues that it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the teachings of the Barry reference by utilizing the fuel of Barry in a common rail fuel system compression ignition engine because one would utilize a known diesel fuel in any diesel engine regardless of the specific use and expect the engine to work effectively.

The Examiner dismisses as non-persuasive applicants' arguments that the use of lower density fuels in high pressure common rail fuel injection diesel engines unexpectedly does not result in a power loss.

The Examiner grounds his dismissal of this argument on the basis that the specification is based on the use of three specific fuels whereas the claims are not limited to the specific fuels. He also argues that it is not clear whether the slight differences shown in the acceleration data translates into expected or unexpected power difference. Finally, the Examiner argues that it appears to him that adjusting the amount of fuel delivered to the engine can eliminate any power loss associated with the use of lower density fuels and, therefore, one of ordinary skill would expect low density fuels to be effective in the claimed engine because one would adjust the amounts delivered to obtain the desired results.

Applicants must respectfully disagree with the Examiner on each of these points.

Applicants believe Barry is not relevant for the reasons previously stated and support the previous arguments and address the Examiner's current observations below.

Applicants respectfully point out that the three examples presented in the present application are just that, they are non-limiting demonstrations of the present invention and are not presented as the only fuels which meet the claims of the present invention. In each case they demonstrate that with respect to UK LS ADO, presented as the base line fuel, the three diesel fuels of lower density, i.e. Swiss LS ADO, R-Improved ADO and Swedish Class 1 ADO, demonstrate that diesel engine equipped with a common rail fueling system can achieve both emissions reductions and no significant loss in power as demonstrated by acceleration performance. The three diesel fuels used as examples have densities of 0.825, 0.821 and 0.815 g/cm^3, respectively. In all three exemplified instances the emissions were reduced with respect to the UK LS ADO base line values, while power loss, as evidenced by differences in acceleration performance, was shown to be not significant. There is nothing in the case and no suggestion made by Applicants that this discovery is limited to the three specific fuels exemplified but rather that this discovery will be true for lower density fuels in general. While the Examiner argues that the claims are not limited to the three specific fuels, Applicants respectfully submit that there is nothing in the case, nor in the art, suggesting that the claims should be or must be limited to these three fuels. The claims have been amended to bring them more closely into alignment with the data in that the claimed density has been changed from about 0.83 g/cc or less to about 0.825 g/cc or less and the viscosity has been changed from about 3 cSt or less to about 2.6 cSt or less, thus reflecting the specifications of the Swiss LS ADO and the R-Improved ADO.

Consequently, it is believed that the claims as amended more closely align with the examples and that further limitation or restriction is not necessary or warranted.

While the SAE article may suggest that a way to compensate for power loss is to adjust the injector pump delivery flow for equal power, this was not done in the examples in the present application. In all four examples (UK SL ADO as base line high density fuel, and Swiss LS ADO, R-Improved ADO and Swedish Class 1 ADO as

examples of low density fuels) the engine and fuel system settings were held constant. Thus, the emission data and acceleration performance data all reflect just the difference associated with the different fuels and not changes or adjustments to the engine, fuel system or drive train of the test vehicle.

With respect to the question of whether the slight differences in acceleration which are shown in the data are expected or unexpected power difference in view of the SAE paper, the Applicants present the following.

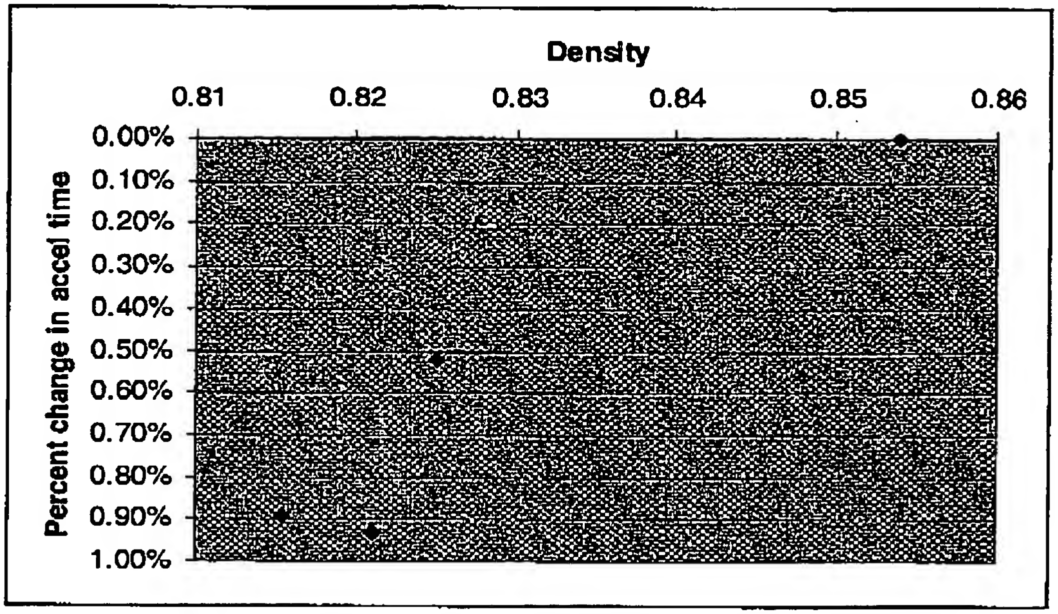
The present invention is directed to the reduction of emissions from common rail fuel system diesel engines by use of low density diesel fuel of lower viscosity, the reduction in emission being achieved without significant power loss.

In other diesel engines, fueled by systems other than common rails, low density diesel fuels reduce emission but at reduced power. As is shown in the SAE reference, reduction in fuel density is associated with engine power loss.

To determine if the slight differences in acceleration shown by the data in the present application is expected or unexpected, the data is analyzed below.

Fuel	Density (g/c)	Accel. Time (sec.)	Density % Difference From Base Fuel	Accel. Time % Difference From Base Fuel
UK LS ADO (base)	0.8539	26.61	0.00	0.00
Swiss LS ADO	0.8251	26.75	-3.49	0.52
R-Improved ADO	0.8212	26.86	-3.98	0.93
Swedish Class 1 ADO	0.815	26.85	-4.71	0.89

A plot of density vs. percent change in power loss is presented in the Figure below:



A linear fit of the plot gives a slope of 0.24% power loss percent for every 0.01 g/cc change in density. Expressed differently, a change of 0.04 gm/cc results in approximately a 1% power loss.

Attention is now directed to the information presented in Figure 1 of the SAE reference. That Figure was reproduced from a paper by P. Heinze which was published in 1986: Institute of Mechanical Engineers International Conference on Petroleum Based Fuels and Automotive Applications, Paper No. C306/86, copy attached.

In Figure 1 discrete data points are presented only for Engine D. There are no data points presented for any of the other engines. All that is presented for the other engines are estimated straight line regressions.

Aside from Engine A, all the other engines showed a larger response (power loss) to density reduction than the common rail fuel system diesel engine exemplified in the present invention.

Engine D in Figure 1 shows the largest power loss as density decreases. In Section 3.1 of the paper "Engine Performance and Emissions with Future Type Diesel Fuels" P. Heinze (C306/86) at page 89, it is reported that Engine D exhibited a 1.6% power increase per 0.01 g/ml density increase. Expressed differently this is a 1.6% power loss per 0.01 g/ml (0.01 g/cc) density decrease.

Engine G in Figure 1 has the smallest density effect (aside from Engine A to be addressed below). For Engine G the power loss/density slope can be estimated from the Figure 1 at delta y = 2.5% / delta x = [0.875 - 0.835] = 0.04. This works out to approximately 0.63% power loss for a density reduction of 0.01 gm/cc. This is more than two and a half times greater than the 0.24% power loss for a density reduction of 0.01 gm/cc shown in the present invention.

Engine A has the smallest density effect. For Engine A the power loss is reported in Section 3.1 of C306/86 at page 89 as being 0.4% per 0.01 g/ml density decrease. While on its face this would appear to indicate that in Engine A the lower density fuel effect is trending in the same or similar direction as the discovery that forms the bases of the present invention, this interpretation would not be complete.

Of the nine (9) engines evaluated on fuels of different densities and reported in Figure 1 of the SAE paper and in C306/86, eight (8) showed significant, substantial power losses as the fuel density decreased, the power loss ranging from somewhere about 0.63% power loss per 0.01 g/cc density reduction to 1.6% power loss per 0.01 g/cc density reduction, these power losses being from <u>more than 2.5 to more than 6 times the power loss per 0.01 g/cc density reduction of the present invention with common rail fueled diesel engines.</u>

One of ordinary skill in the art, with this type of information before him would not expect that in common rail fueled diesel engines, a percent power loss of only

0.24% per 0.01 g/cc density reduction would be obtained while still achieving reduced emissions. On the contrary, one would not know nor could it even be guessed what the percent power loss per 0.01 g/cc density reduction would be for the engine. Therefore, while it might be obvious to try fuels of different lower density in any diesel engine to achieve an expected reduction in emissions, <u>one would expect a power loss</u> to be sustained, with no real expectation that it would not be somewhere between about 0.63% to 1.6% power loss per 0.01 g/cc density reduction, the type of data reported for eight (8) of the nine (9) engines tested. Indeed, even considering all nine (9) fuels, the power loss ranged from 0.4% to 1.6% power loss per 0.01 g/cc density reduction which is even at the low end, about double the 0.24% power loss per 0.01 g/cc density reduction observed in the present invention. Because all engine <u>types</u> are different it was not possible to predict based on any of the showing of the references that the power loss in common rail fueled diesel engines would be only about 0.24% per 0.01 g/cc density reduction in the diesel fuel used to power the engine and that low density fuel would or could achieve both emissions reduction and minimal power loss in such engines.

Engine A does not demonstrate the present invention: it does not demonstrate the same reduction in emissions with a minimal percent power loss.

Reference is made to Figure 6 in the 1986 paper C306/86. Figure 6 reports the level of emissions for six (6) engines including Engine A. In the 1986 paper, the density range for emission testing is 0.874 to 0.837 g/cc. Figure 6 shows the general emissions trend for Engines A, B, E, F, G and H.

In the present invention, over a density range of 0.8539 to 0.8155 g/cc (delta of 0.0384 g/cc), HC goes down significantly, CO goes down significantly, and NO_x remains relatively unchanged while percent power loss, as previously demonstrated, goes down relatively insignificantly (0.24% power loss per 0.01 g/cc density reduction).

Engine A showed a relatively smaller CO emissions reduction benefit from the use of low density fuel. Engine A is a direct injection engine and emissions data are shown in Figure 6. The data for CO are most telling. Over the range of densities tested in the present invention (0.8539 → 0.8155 g/cc for a density delta of 0.0384 g/cc) a CO reduction of at least 63% was achieved (CO went from 0.77 down to about 0.28). The emissions testing results presented in the present invention were generated using the regulated emissions test cycle. Engine A shows a CO reduction of about 25% over a density range of between about 0.860 to 0.837 g/cc for a delta of 0.023 g/cc. While it is to be noted that in Figure 6 the x axis is cetane, reference to Table 1 of Paper No. C306/86 reveals that the fuel with the cetane of 53 had a density of 0.837 g/cc while the fuel with a cetane of about 46 had a density of 0.860. Extropolalating to a cetane of about 41 (density of about 0.874 g/cc) one would expect engine A to exhibit a change in CO of from about 7.3 down to about 4.5 for an about 38% reduction in CO over a density change of about 0.038 g/cc, the same density change as exemplified in the present application. Based on the results presented in the Paper No. C 306/86 it is maintained that there is no way to derive from these results that one could or would expect large emission reduction benefits (greater than about 60% CO reduction over a Δ density of about 0.038 g/cc) AND low power loss in common rail fueled vehicles (0.24%/0.01 g/cc density reduction, versus the best data in C306/86 of about 0.4%/0.01 g/cc density reduction).

Thus, Engine A does not achieve the same reduction in emissions at <u>minimum</u> % power loss as is demonstrated in the present invention. Engine A achieves (based on extrapolation) about a 38% reduction in CO, whereas in the present invention a CO reduction of greater than about 60% is achieved over the same change in density (about 0.038 g/cc) and at a low loss of power.

Consequently, with the present art before him one skilled in the art would not know what to expect when using a diesel fuel of reduced density <u>in a common rail</u>

fueled diesel engine. It is not at all apparent that in a common rail fuel system diesel engine a diesel fuel of reduced density will reduce CO and HC emission while holding NOx at least constant and at a percent power loss of only about 0.24% per 0.01 g/cc density reduction as demonstrated in the present case as compared against the results from C306/86 for which 8 of 9 engines showed percent power loss ranging from about 0.63 to 1.6% per 0.01 g/cc density reduction while for Engine A a percent power loss of about 0.40% per 0.01 g/cc density reduction is accompanied by a reduction in CO of only about 38% versus the present invention wherein a percent power loss of about .24%/0.01 g/cc density reduction is accompanied by about a 63% reduction in CO exemplified in the present invention for common rail fueled diesel engines.

Thus the result of the present invention is considered to be unexpected based on the data in the present application in light of the teachings in the literature.

It is requested that the Examiner reconsider the present application in light of the amendment made to the claims, and the arguments made above, that he withdraw the rejection, allow the claims and pass the case to issue in due course.

Respectfully submitted,

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